Issued September 15, 1911.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE—BULLETIN 91.
HENRY S. GRAVES, Forester.

GRAZING AND FLOODS:

A STUDY OF CONDITIONS IN THE MANTI NATIONAL FOREST, UTAH.

BY

ROBERT V. R. REYNOLDS,
FOREST EXAMINER.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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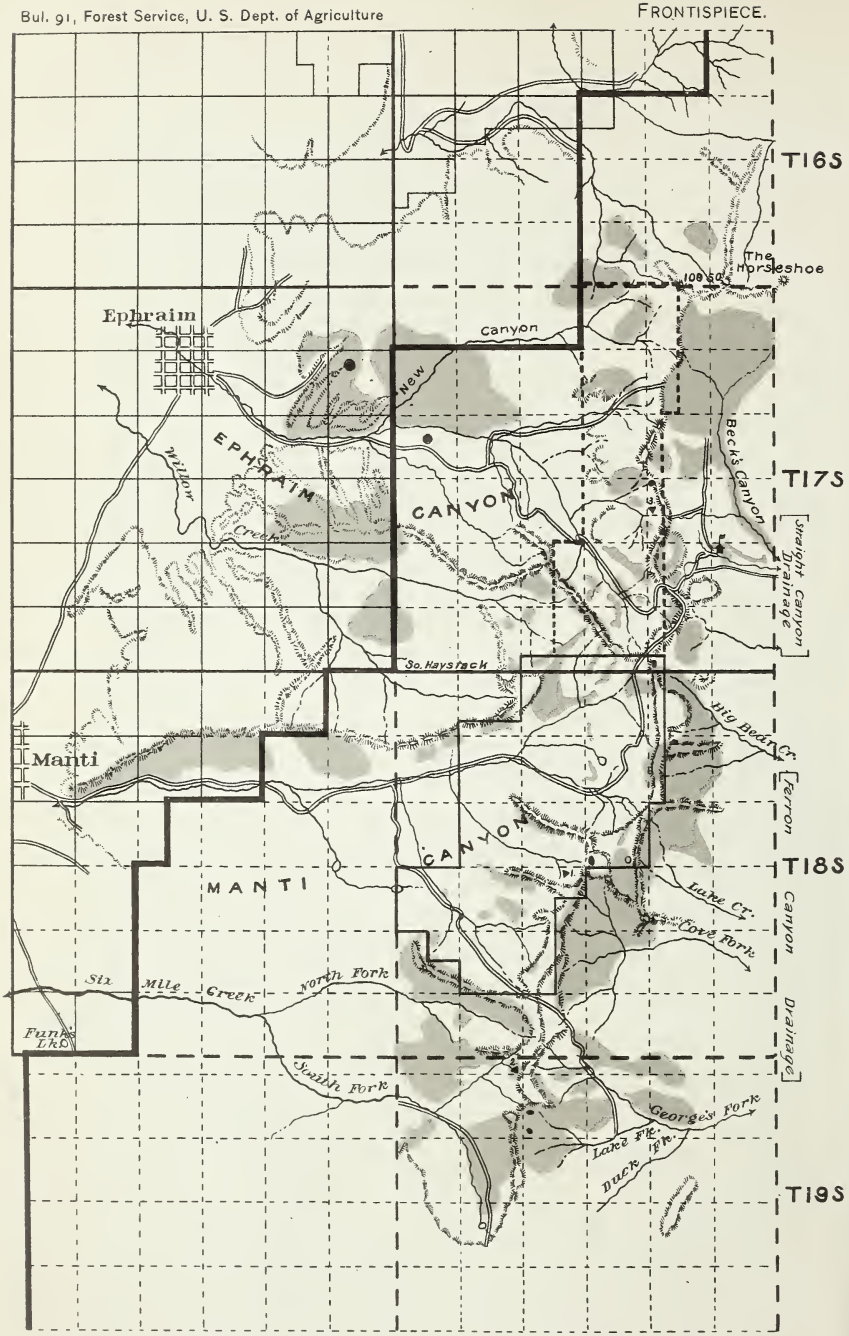

LEGEND

Forest Boundary. ▲ Rain Gauge. Proposed closed Area, Ephraim Canyon.

Area closed to grazing, Manti Canyon. Bare Areas caused by rock outcrop, erosion, or over-grazing.

MAP OF
EPHRAIM AND MANTI CANYONS.

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
FOREST SERVICE,
Washington, D. C., June 1, 1911.

SIR: I have the honor to transmit herewith the manuscript entitled "Grazing and Floods: A Study of Conditions in the Manti National Forest, Utah," by Robert V. R. Reynolds, and to recommend its publication as Bulletin 91 of the Forest Service.

Very respectfully,

HENRY S. GRAVES,
Forester.

Hon. JAMES WILSON,
Secretary of Agriculture.

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A STUDY OF CONDITIONS IN THE MANTI NATIONAL FOREST, UTAH.

INTRODUCTION.

An exceptionally good illustration of the harmful effect of overgrazing upon streamflow is afforded by that portion of the Wasatch Mountains embraced within the Manti National Forest in central Utah. This region has for a number of years been subject to severe floods after all storms of more than usual violence, with corresponding scarcity of water during periods of drought. A careful study made during the spring and summer of 1910 showed clearly that this condition of erratic run-off had followed heavy overgrazing in the mountains, and that where grazing had been restricted the conditions were rapidly improving. The problem of securing an equable streamflow is a vital one to the towns located along the base of the Wasatch Range. These are not only dependent upon the streams for their water supply, but they have also suffered heavily from floods in the past and are still constantly in danger.

GRAZING HISTORY.

The region of the Manti National Forest was first settled about 1850. From that time until 1880 a gradually increasing business in the grazing of cattle and horses was built up by settlers. The mountains afforded excellent and spacious summer range, and in winter the stock were either run upon the desert lowlands or, to a less extent, fed upon the produce of the farms in the valleys.

The range cattle business was at its height in 1880, when the sheep business first began to take foothold. From the first, sheep were more profitable than cattle for those who were able to secure enough summer range. A long struggle ensued between the sheepmen and the cattlemen, with the final defeat of the latter. Throughout this fight for control of the summer range, tactics were employed by both sides to oust their adversaries, which caused great damage to the range itself. Flocks were handled close bunched in bedding, in feed-

ing, and in maneuvering to obtain control of the choice areas, and were moved over a far greater area than was necessary. Hundreds of fires were set under the mistaken idea of "improving the range," and to burn out dense areas of brush in order that the sheep might penetrate them. In the fall, upon leaving the summer range, it was customary to set fires on the way out, and in that way much green timber also was killed.

As the contest between the sheepmen and the cattlemen, and between rival sheepmen became more severe, the carrying capacity of the range rapidly diminished, and more travel on the part of the grazing stock became necessary to secure enough feed. The result was that, between 1888 and 1905, the Wasatch Range, from Thistle to Salina, was a vast dust bed, grazed, trampled, and burned to the utmost. The timber cover was reduced, the brush thinned, the weeds and grass cropped to the roots, and such sod as existed was broken and worn. The basins at the head of the canyons suffered most, relatively, because they contained the best feed for sheep and were less broken in topography and more easily accessible. Their scanty timber cover, however, made them particularly liable to removal of the soil by wind action wherever the surface cover was broken through and dry powdered earth exposed. These high mountain pastures, therefore, received not only the most abuse, but have been proportionately longer in recovering from its effects.

In March, 1902, a large area was withdrawn from entry for the Manti National Forest, and on May 29, 1903, President Roosevelt created the larger part of the present Forest. Subsequently additions were made, mainly at the northern end.

Upon beginning administration of the new Forest the action of the Land Office was prompt and vigorous. On August 18, 1903, the Commissioner of the Land Office ordered all sheep removed from the western slope of the mountains. This order was carried into effect at the beginning of the following grazing season.

On the same date the commissioner ordered the supervisor to prohibit all grazing on an area of 8,830 acres covering all the uplands of Manti Canyon, as shown on the map (frontispiece). From the beginning of the following grazing season (1904), cattle and horses, as well as sheep, were therefore excluded from this area. Early in 1909, upon representations made by the stockmen, the Forest Service decided that drifting cattle and horses from the neighboring canyons to the amount of 300 head would thereafter be allowed in the closed area. Hence the area was closed completely against all grazing for five years, and during 1909 and 1910 was grazed by about 1 head for each 30 acres of the total area. The area which can actually be grazed is, however, so reduced by bare rock and

inaccessible hillsides that the true ratio is more nearly 22 or 24 acres of grazing land to each head of stock.

PAST FLOODS.

Inquiries made of a number of men living in different parts of the Forest, including lawyers, farmers, stock raisers, and Forest rangers, showed that serious floods had occurred in the years 1888, 1889, 1893, 1896, 1901, 1906, 1908, 1909, and 1910. It is noteworthy that no serious flood is reported from any canyon prior to 1888, at which time the sheep business had been in operation for about six or seven years, and the range was already becoming badly depleted. Since that year floods have occurred frequently in one part or another of the Forest. An equally striking fact is that the last serious flood in Manti Canyon occurred in August, 1902, before any effort was made to protect it from overgrazing. The exclusion of all stock from the protected area for the five years from 1904 to 1909 gave the uplands a chance to become well reclothed with vegetation before the bad flood season of 1909.

The beneficial results obtained from the protection afforded Manti Canyon were forcibly shown in August, 1909, when Ephraim and Six Mile Canyons were flooded severely, while Manti Canyon, lying between them, was not perceptibly affected. Both Ephraim and Six Mile Canyons were heavily overgrazed by sheep from 1882 until the establishment of the Forest in 1903, and have since then been closely grazed by cattle. Accordingly, there is at present a much better soil cover in Manti Canyon, and there seems to be no reasonable doubt that to this fact it owes its escape from the floods of August 17 and 31, 1909.

Certain sheepmen have claimed that the storms which flooded Ephraim and Six Mile Canyons split, and that not enough rain fell in Manti Canyon to cause a flood. This argument, however, does not appear to be tenable. In the first place, it is certain that the storms come from the southwest, and that on August 31 it rained hard enough to cause floods in Twelve Mile, Six Mile, Willow Creek, and Ephraim Canyons, and in all of the canyons opposite them on the east side of the range. It is not conceivable that cloud-bursts should have occurred on areas which practically surround the head of Manti Canyon, and that it alone should have escaped. Secondly, a thoroughly reliable ranger, who was in the head of Manti Canyon during the storm of August 17, states that for at least three-quarters of an hour it rained hard, so that the ground everywhere was flowing with water.

Three rain gauges have recently been set up in Six Mile, Manti, and Ephraim Canyons, and by means of these it will be possible in the

future to determine definitely the precipitation in each canyon during any storm. The readings made from these gauges up to June 1, 1911, were as follows:

	No. 1 gauge, Manti Canyon.	No. 2 gauge, Six Mile Canyon.	No. 3 gauge, Ephraim Canyon.
1910.			
Aug. 11	0.22	0.36	0.37
Sept. 2	.11	.11	.09
Sept. 16	1.51	1.98	1.16
Sept. 21	1.18	1.18	1.59
Total	3.02	3.63	3.21

Final conclusions can not be drawn from records covering so brief a period. It is of interest to note, however, that the rainfall in Manti Canyon on September 16 exceeded the fall in Ephraim Canyon by 0.35 inch, from which fall no flood resulted.

The reading of the gauges on September 21 shows the combined precipitation of two heavy rains which occurred, respectively, on September 18 and September 19, 1910. The watershed had previously been thoroughly soaked by the rain recorded on September 16. The effect noted in Ephraim was a flood which passed through some of the principal streets on September 18, leaving a thick layer of mud and filling ditches, culverts, cellars, and basements with filth and débris. Many lawns, gardens, and orchards were covered with mud, and much damage was done to grain fields west of the city. On the following day high water again came down Ephraim Canyon, but did little damage, as the volume discharged was not so great and less mud was carried. Local Forest officers estimate that the damage done in Ephraim on these two days was approximately $1,000. There is no record of any damage in Manti on these dates, or even of discharge approaching the dimensions of a flood.

On these two days the combined precipitation in Ephraim Canyon exceeded that in Manti Canyon by 0.41 inch.

On the other hand, it should be remembered that the area of high mountain watershed of Manti Canyon, which has elevation sufficient to induce heavy precipitation, bears the proportion of nearly 9 to 5, compared with the similar lands in the Ephraim watershed. The volume of water which the respective canyons had to discharge depends upon the depth of the rainfall and also upon the surface drained. Multiplying the gauge readings by the coefficients representing surface we obtain

$$1.18\times 9 : 1.59\times 5 = 10.6 : 7.9.$$

This proportion indicates that on September 18 and 19, while Ephraim Canyon was flooded twice and Manti Canyon had no flood,

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SEVERELY O
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cover patchy from

to make a bond

FIG. 1.—PANORAMA OF BASINS AT THE HEAD OF EPHRAIM CANYON, WHICH FLOODED SEVERELY ON AUGUST 17, 1909.

The white spots are limestone, laid bare by erosion resulting in part from overgrazing. Timber cover inadequate to restrain floods, and ground cover patchy from excessive grazing.

FIG. 2.—PANORAMA FROM EAST EDGE OF MAIN DIVIDE IN SECTION 28, TOWNSHIP 18 S., RANGE 4 E., ACROSS BASIN AT HEAD OF COVE CREEK. SHEEP RANGE.

Barrenss due to erosion, rock outcrops, and over-grazing.

This proportion indicates that on September 18 and 19, while Ephraim Canyon was flooded twice and Manti Canyon had no flood,

to make a bond

FIG. 1.—HEAD OF LEFT FORK OF EPHRAIM CANYON.

A 30° slope below area completely denuded by overgrazing; eroded and unable to reclothe itself with ground cover. Note limestone cap of plateau.

FIG. 2.—PANORAMA ACROSS HEAD OF MIDDLE FORK OF SIX MILE CANYON.

Bareness due to erosion, rock outcrops, and overgrazing. Formerly grazed by sheep, cattle and horses. 977 head of cattle and horses are now permitted to entire canyon. Note erosion gullies.

the latter canyon was easily handling the run-off of a volume of water approximately 25 per cent greater than that which was rushing from the Ephraim watershed.

It should also be remembered that the fall of 1.51 inches (which caused no flood) in Manti Canyon is only 0.08 inch less than the fall of 1.59 inches in Ephraim Canyon, which was sufficient to cause two distinct floods on successive days.

Up to the present time the Manti Canyon gauge shows less precipitation than either of the two others. Theoretically, as the number of observations increases these totals should gradually approach equality, but it may be found that the removal of the surface cover in Ephraim and Six Mile produces abnormal fluctuations in temperature, due to a smaller percentage of water in the air, which actually induce more violent precipitation in these two canyons.

Taking all the facts into consideration the absence of floods in Manti Canyon can be attributed only to the protection afforded by the excellent crop of forage on the area closed to grazing. The growth of grass and weeds in the bottoms of the gullies and on the slopes was sufficient to delay the run-off until the water soaked in, while at the same time the earth was not so completely trampled by the constant traveling of stock as in the other canyons.

DAMAGE FROM FLOODS.

Nearly all of the towns located along the base of the mountains have, at one time or another, suffered damage from floods. Torrents of muddy water bearing heavy bowlders, logs, and driftwood have swept down from the mountains and deposited thick layers of foul-smelling mud in the houses and on the lawns, broken down standing grain, and left the fields covered with piles of gravel, bowlders, and driftwood. Among the items of damage and injury are included destruction of roads, bridges, streets, and buildings; expense for the removal of mud, gravel, bowlders, and timber from streets and agricultural lands, and for the construction of dams; damage to stored goods and railway tracks; heavy depreciation of real estate values; ruin of crops; permanent injury to agricultural lands; delay of business; filling up and destruction of reservoirs, canals, and ditches; sickness; and even death.

It is estimated roughly that a total loss of $225,000 has been caused by floods. The town of Manti alone, which is located directly at the mouth of Manti Canyon and close to the base of the hills, has suffered damage which is variously estimated at from $75,000 to $125,000. Other towns which have suffered heavily are Mount Pleasant, Ephraim, Salina, Ferron, Huntington, and Orangeville.

On the eastern side of the mountains the steadily increasing losses finally made it necessary in 1909 for Emery County to make a bond

issue of $35,000, to be used for the sole purpose of reconstructing and repairing damage done to roads and bridges. This money is only sufficient to do what has to be done to make travel possible on the most important highways. It does not include the reconstruction of the road from the settlements to the mountains, which is used by the people to secure their supplies of lumber and timber. To rebuild this road will cost many thousand dollars more, and the people at present are entirely unable to undertake it. Furthermore, the destruction of reservoirs and the deposit of sand and gravel in canals and irrigation ditches represent a far greater loss to the people than the expense of repairing roads and bridges.

In 1910 a committee composed of two sheepmen, two cattlemen, and a merchant, representing the towns of Orangeville and Castledale and surrounding agricultural settlements in Emery County, expressed the belief that these floods are due mainly to the denuded condition of the range which has resulted from overgrazing, and requested the protection of these watersheds. In support of their request they stated that for many years after the settlement of Castle Valley in 1878, floods were unknown. Soon after the ranges on the heads of the streams were heavily stocked with sheep and cattle, however, freshets began to occur with each heavy rain during the summer months, and these have steadily increased in volume and destructiveness. So great is the burden of constant repair of roads, bridges, and irrigation systems now necessitated by the recurrence of floods that many of the settlers in Castle Valley, which has a population of about 8,000, are becoming greatly discouraged, and are giving up their farms and seeking employment in the nearby coal mines and elsewhere. It was the opinion of the committee that if a strip 2 miles wide on the heads of the canyons were closed to all stock, the damage from floods would be greatly reduced as soon as the ground cover had had an opportunity to recover from the effects of overgrazing.

In addition to the loss of property, the floods have resulted in the destruction of many fish. All the mountain streams were formerly of clear cold water, and were fairly well stocked with trout. Residents state that in early days the water never became muddy after a storm, whereas the erosion has now become so great that on the western slope the streams are turbid after every rain. The fish have been killed in the thick mud brought down by floods, until at present the trout fishing is very poor, and in some canyons no fish can be found except such as have been introduced. The total disappearance of the native trout from streams known to have been well stocked in former years is in itself a significant fact, pointing to a fundamental disturbance of conditions in the run-off. Nor can this change be attributed entirely to dynamiting or to the increase in the number of

fishermen, for neither dynamiting nor legitimate fishing would remove from any stream all the individuals of a given variety.

EFFORTS TO PREVENT DAMAGE.

Until the area in the head of Manti Canyon which was closed to grazing in 1903 should have recovered sufficiently to have an appreciable effect in preventing floods, the people of Manti found it necessary to provide other protection for the town. The mouth of the canyon is very narrow and very close to the town, so that the full power of every flood was discharged directly into the village without having time to spread out on any intervening flat. Bowlders and logs had to be hauled out of the bed of the stream by teams, in order to clear the streets and to prevent the stream from becoming so obstructed that its course would be changed.

Accordingly, in 1903, under the advice of the State engineer, two large dams of bowlders were built just inside the mouth of the canyon. These dams were simply orderly piles of bowlders built up across the stream bed with no attempt to make them water-tight. The only purpose was to hold back the bowlders and logs which came down with the floods and with the usual high water in the spring, and to let the water pass on through. This purpose the dams have served very well, and they are now level full of gravel, silt, and bowlders (Pl. III, fig. 2). Each year the crest of each dam is built up to hold the yearly accumulation of débris. The upper dam is 200 feet across the top from bank to bank and about 20 feet from crest to base. The lower dam is 100 feet along the crest and about 35 feet from crest to base at the deepest place. A spillway has been tunneled around the north end, through the solid rock, to provide for free drainage.

A similar dam of bowlders was constructed in 1905 in Ephraim Canyon, within a mile and a half of the town of Ephraim, but is entirely unable to cope with the volume of débris which repeated floods still bring into the town. The only efficient check upon erosion will be to restore the normal conditions at the head of the stream.

In the flat on the west side of the town of Manti the tortuous course of the stream was straightened for several miles by cutting a canal to the San Pitch River. This provides ample drainage and prevents the water from backing up into the town or from spreading over the agricultural lands.

CONDITIONS AFFECTING FLOODS.

TOPOGRAPHY.

The portion of the Wasatch Range under consideration consists of alternating layers of white limestone and sandstone, with little or no rock of volcanic or igneous origin. Apparently there was once

a great tableland, or a rounded uplift, of which the topmost layer was a thick stratum of limestone. This tableland has since been eroded, until there now remains of it only the main divide, which in some places is a narrow ridge extending nearly north and south, and in others broadens into a considerable plateau. The average altitude of the main divide is slightly over 10,000 feet, and the highest point within the region discussed is Horseshoe Mountain, with an elevation of approximately 11,000 feet.

The topography is not very rough for western mountains and forms a strong contrast to those ranges which are formed by igneous rocks, as is the case in the Wasatch National Forest, where sharp peaks and steep cliffs are a common feature. The limestone has resisted erosion much more effectively than the sandstone, as is shown by the nearly level calcareous cap which remains on the divide, and also by the fact that at the head of each large canyon is a basin of comparatively gentle slope which is sustained by the limestone layers near the top. This basin region has a width of from 1 to 2 miles on each side of the divide. After the limestone layers have once been completely cut through, the soft and coarse sandstone is readily eroded, and deep gorges are formed. As a result the canyons are unusually steep; Ephraim Canyon, for instance, has a grade of about 12½ per cent, or over 7°, and many of the hillsides are so steep as to lie at an angle of from 20° to 30° with the horizontal. This steepness of slope naturally contributes to rapidity of run-off and greatly increases the danger of floods as well as the damage from erosion.

SOIL.

The soil consists mainly of sandy loams of various degrees of fineness, often mixed with calcareous gravels. A deep soil of this character in fairly level country and with a good ground cover would absorb water quite readily and would tend to equalize the run-off. In this particular region, however, because of steep slopes and lack of ground cover, the soil is very easily eroded and in many places is only a few inches deep. With recovery of the range through protection from grazing, this erosion would largely be prevented and at the same time the danger of severe floods would be decreased.

GROUND COVER.

Where the ground is covered with vegetation, whether of trees, shrubs, or grasses, rapidity of run-off is decreased, and the tendency toward floods is diminished. A good example of this on a small scale may be afforded by two adjacent steep slopes, one well covered with sod, the other bare. The stream from a garden hose may be directed for hours against the sodded slope without doing per-

ceptible damage, while in the same period deep holes will be washed in the face of the bare slope, gullies formed, and hundreds of pounds of earth washed down. The grass breaks up the stream of water, restrains its speed in running off, and binds the earth in place.

In that part of the Manti National Forest under consideration the timber cover is so scattering as to be of no effect, and the shrub and grass cover is badly broken, exposing in the aggregate large masses of unprotected earth. The range grasses and shrubs were formerly sufficiently dense to protect the watersheds from erosion and to decrease to a minimum the number of floods. These have now, however, been largely destroyed by overgrazing; except in the area from which all grazing has been excluded, conditions are not improving rapidly and in places seem to be becoming worse. The restoration of this depleted cover is absolutely essential to check the damage now caused by frequent floods.

RAINFALL.

Precipitation in the Wasatch Mountain takes place in such a way as to be particularly favorable to the occurrence of floods. Although the total annual precipitation of the region is not great, storms of cloudburst violence are not infrequent during the summer and spring. These heavy storms nearly all come from the southwest, and are frequently very limited in extent. No accurate figures of rainfall are available, but it is probable that it sometimes reaches as high as 1 inch in a given hour, and that the rate of fall may even be 2 inches per hour for a few minutes at a time. The soil is unable to absorb this great amount of water immediately, and as a result there is a tendency for it to flow off from the watershed in the form of a flood. The months in which floods are most likely to occur are August, May, July, and September, in the ratio of approximately 15, 6, 2, and 1, respectively.

TORRENTIAL RUN-OFF.

One of the chief factors in increasing the damage from floods is the formation of a system of gullies. These form lines of least resistance to the passage of the water and consequently increase the rapidity of the run-off and its transporting and cutting power. This gully system begins a short distance below the divide as furrows from 1 to 6 inches in depth and width. As these extend down the slope they join neighboring furrows and become rapidly wider and deeper until large gullies 7 or 8 feet deep are formed.

When a heavy rain occurs on a slope where no gullies exist, the water flows off in a thin sheet everywhere evenly and strongly retarded by friction against the surface of the earth. As soon as a

gully system is formed, however, the water is not only gathered into definite streams, but its velocity is also greatly increased. It is obvious that the main resistance to the run-off of the water is against the sides and bottom of the gully, while the friction of the water in the middle of the stream against surrounding water particles is comparatively slight. Accordingly, as a gully increases in size the friction increases only in direct proportion to the dimensions of the channel, while the discharge increases as the product of the dimensions. Thus, if the dimensions of the gully are increased 10 times the friction is also increased approximately 10 times, while the volume of the discharge is increased approximately 100 times. Where the hills are thoroughly drained by a system of gullies, therefore, the water from a storm sweeps down through them in a fraction of the time that would be required if it had to trickle down in a thin sheet. The main channel of the canyon is unable to discharge the influx of water as fast as it rushes in, and the result is a flood.

On the other hand, the rapid enlargement of gullies is prevented to some extent by the tendency of pebbles and bowlders to cover the bottom of a wash. These form a floor which resists erosion far more effectively than the underlying earth, and also by its roughness tends to reduce the rapidity of run-off. Often also gullies are cut back to solid rock, and their further enlargement then becomes a matter of many years.

The high rate of run-off which is characteristic of streams in the Manti National Forest enables them to carry down bowlders of extraordinary size. (Pl. IV, fig. 2.) The transporting power of water varies as the sixth power of its velocity, so that if the velocity of a stream is increased 10 times, for instance, its transporting power is increased 1,000,000 times. A current of 2 miles per hour will move fragments of stone the size of a hen's egg, weighing about 3 ounces, while a torrent of 20 miles per hour will carry bowlders weighing nearly 100 tons. In the case of the streams flowing from the Manti National Forest, bowlders weighing up to 3 or 4 tons have been brought down to the mouths of the canyons, and in some cases through the towns. This would indicate a current of about 13 miles per hour, and it is probable that a velocity of from 10 to 12 miles per hour is not unusual.

The erosive or abrading power of a stream varies as the square of its velocity. When the stream is loaded with gravel and bowlders, however, these act as tools to grind, cut, or drive all obstacles from their path and greatly increase its power of erosion. In irrigation ditches a slope of approximately 3 feet per mile will give the water sufficient velocity to cut away rapidly banks of soft, sandy soil. Since the canyons in the Manti Forest have an average slope over

200 times as great, it is evident that the erosive power of the streams is enormous.

The amount of water discharged by these flooded canyons after a cloudburst is almost incredible. Many observers state that the streams in flood have a cross section of from 100 to 1,000 square feet, and that the flood waters continue to flow for a period of from 1 to 24 hours, although the usual flow is not over 6 hours. A stream with a cross section of only 250 square feet and with a velocity of 10 miles per hour would, in the course of 4 hours, discharge 2,000,000 cubic yards, or 1,687,500 tons of water. The damage that may be done by torrents of this character is obvious.

FUTURE REGULATION OF GRAZING.

In 1910 Ephraim Canyon was grazed by 1,354 head of cattle and horses; Manti Canyon, below the fence of the closed area, by 479; and Six Mile Canyon by 977. On the eastern side of the divide, opposite these canyons, more than 20,000 head of sheep were permitted to graze in the basins between Horseshoe Mountain and Duck Fork of Ferron Canyon for from one to two and one-half months. Eliminating the bare rock and timber, this strip provides not more than half an acre of grazing land for each sheep.

There is no doubt that Ephraim Canyon is badly overgrazed. The 1,354 head of stock permitted in the entire canyon are presumably allotted on a basis of total acreage, but they concentrate on the uplands. Early in the season they graze on the lowlands, but as the snow recedes they push for the higher elevations. They also prefer to be on the open uplands rather than in the thick timber or on the rough hillsides lower down. In the fall they go back to the lower elevations after the highland feed has been thoroughly frost killed, but it is probable that 70 per cent of the 1,354 head spend nearly two-thirds of the season (three months) on the upland area of approximately 5,700 acres. This provides 6 acres per head for three months, which is entirely insufficient except in the best of feed. Under this treatment the range can not recover from former abuse sufficiently to prevent further floods.

Provision has now been made to protect the watersheds from further damage by making a reduction of 2,000 head in the number of cattle and of 27,000 head in the number of sheep which will be allowed to graze upon the Forest.

In order to allow the overgrazed lands on the eastern side of the mountains to recuperate, a strip of approximately 2 miles in width running east from the top of the divide will be entirely closed to sheep until after August 20, by which time the important range grasses will have ripened and shed their seeds. Ephraim Canyon will also

be protected by reducing the number of stock allowed to graze there so far as is practicable without the construction of a drift fence. Manti Canyon, on the other hand, as a result of the protection previously afforded it, has now recovered sufficiently so that 500 head of cattle and horses will hereafter be allowed to drift upon it, unless it is found that this increased number is sufficient to injure the range.

SUMMARY.

Heavy precipitation, steep slopes, and a comparatively scanty forest cover all tend to favor the occurrence of floods in the streams flowing from the Manti National Forest. This tendency was formerly counteracted to a great extent by an abundant ground cover of shrubs and grasses, which delayed the run-off and prevented erosion.

Previous to 1888 there is no record of serious floods in this region. Heavy grazing by horses, cattle, and especially by sheep resulted, however, in the almost complete destruction of this cover. Since 1888 floods of great violence and destructiveness have been common, and it is estimated that they have caused a total loss of approximately $225,000.

Upon the creation of the Manti National Forest in 1903 prompt action was taken to prevent further damage to the range from overgrazing. Since 1903 no sheep have been allowed on the west side of the divide. Manti Canyon was still further protected by excluding all stock from an area of 8,830 acres on the uplands from 1904 to 1909. Since then a small number of drifting cattle and horses have been allowed on the area. As a result of this protection, range conditions within Manti Canyon have steadily improved, and at the same time it has been less subject to floods. A striking example of this was in August, 1909, when severe floods occurred in Ephraim and Six Mile Canyons, from which stock has never been completely excluded, while Manti Canyon, lying between them, escaped entirely. Also, on September 18 and 19, 1910, two successive floods caused damage of approximately $1,000 in Ephraim. No flood resulted at Manti, although the Manti watershed is nearly twice as great in extent as that which drains through Ephraim. At the request of members of the community steps have now been taken to restrict grazing in the Forest still further. There can be no reasonable doubt that the torrents which have devastated this region within the last 20 years have been caused primarily by overgrazing, and that they can be largely controlled, if not entirely eliminated, by a restoration of the natural protective cover of shrubs and grasses.

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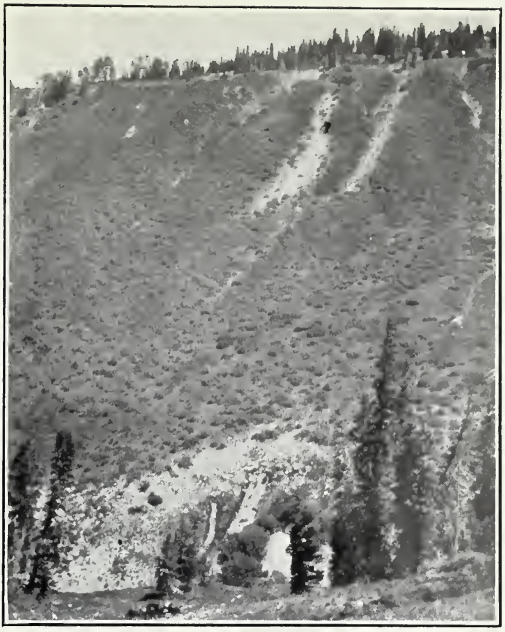

FIG. 1.—A SLOPE OF FROM 30° TO 40° IN THE PROTECTED AREA OF MANTI CANYON.

From 1888 to 1904 this slope was almost absolutely bare from overgrazing, but it is now reclothing itself, gullies and all, with a cover of shrubs and brush sufficient to prevent further washing under ordinary precipitations. Contrast with Fig. 1, Pl. II.

FIG. 2.—VIEW OF UPPER DAM IN MANTI CANYON.

This dam is now nearly full of débris brought down by spring high water, though no floods have occurred since its construction.

FIG. 1.—TOP OF MAIN DIVIDE IN SEC. 28, T. 18 S., R. 4 E.

An area of about 5 acres in which the soil has been blown off the underlying rock and sand. There was once from 1 to 3 feet of soil, as seen near the trees in background.

FIG. 2.—MOUTH OF EPHRAIM CANYON, ABOUT 1 MILE EAST OF THE CITY.

In foreground, bowlders and gravel brought down by floods.

FIG. 1.—VIEW TOWARD HORSESHOE MOUNTAIN, LOOKING UP HEAD OF JUSTERSONS FORK, SEELEY CREEK.

Note outcroppings of limestone rock and gravel through the thin soil. A favorite summer range for sheep. Even this poor ground cover is said to be much better than before establishment of the forest.

FIG. 2.—VIEW AT HEAD OF MIDDLE FORK OF MANTI CANYON.

Note excellent protection cover formed by range grasses and shrubs. This area was grazed as bare as any shown in the previous pictures from 1887 to 1903, before the area was closed to grazing.